

1925.

COMMONWEALTH OF AUSTRALIA.

PETROLEUM.

REPORT ON INVESTIGATIONS MADE IN
NEW SOUTH WALES

BY

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REPORT.

SECTION I.

I. INTRODUCTORY CONSIDERATION OF OIL POSSIBILITIES IN THE STATE OF NEW SOUTH WALES.

The State of New South Wales covers an area of 310,372 square miles. Geologically it may be divided into three almost equal parts. Upper Cretaceous Beds (desert sandstones) cover the north-western section of the State, overlying the Trias-Jura Beds, which help to form the great artesian basin which takes in adjacent parts of Queensland, South Australia, and Northern Territory. Post-tertiary and tertiary sediments occupy the south-western section, sending a narrowing tongue to the north-east, along the outer rim of the great artesian basin, to the borders of Queensland. The third section is a broad belt some 200 miles in width, which runs parallel with the coast for the whole of its length. Avoiding technical terms as far as possible, this belt may be described as being fundamentally an area of fractured masses of granite associated with crushed and contorted sedimentary rocks of Older Palaeozoic age, which are in consequence highly indurated and metamorphosed. This belt also sends out a tongue to the north-east dividing the tertiary and post-tertiary tongue from its main area in the south-west. Two large basin-like depressions occur in this coastal region. The larger, which occupies an immense tract of country around Sydney, is filled with a series of sedimentary deposits of great thickness, and of Triassic, Permian or Permo-carboniferous, and Carboniferous ages. The carboniferous rocks do not appear to completely cover the floor of the basin, but enormous thicknesses of them exist in its northern portion. These sediments have not, for the most part, been greatly disturbed, but they are depressed towards the centre of the basin near Sydney, and rise towards its rim showing that the basin-like form of this old depression has been largely formed or at least accentuated since these deposits were laid down.

The smaller basin occupies an area which is drained by the Clarence River near the Queensland border. It is filled with fresh-water deposits which were laid down in what is believed to have been the Trias-Jura period.

A certain amount of prospecting for oil, together with some boring, has been done in the State, but no positive evidence of its existence which is beyond suspicion has yet been brought to light. Mr. J. E. Carne, the late Government Geologist for New South Wales, in referring to the first section, occupied by the great thicknesses of mesozoic rocks which form part of the great artesian basin, discounts the probability of finding oil in these beds, though the sedimentary types known to occur are not unsuitable to the formation of oil. He lays stress on the absence of certain physical conditions which have been proved govern the occurrence of oil and natural gas in America and elsewhere.* He refers to the undisturbed condition of the beds and the absence of folding. Large volumes of natural gas and some actual evidences of oil have been found during boring operations on the margins of this basin in the Queensland area.† No close geological survey has been made of this part of New South Wales, though a number of deep artesian bores has been sunk in it, and so far as the drilling records go no signs that would lead us to suspect the presence of oil in these rocks have been noted in New South Wales. An examination of the area in detail would take considerable time, for the area is not well served by roads or railways, still I think that the area is deserving of some attention if only on account of its possibilities with regard to natural gas. The area is far from the more settled portions of the State, so that it would probably not pay to pipe gas away from it nor would it pay to pipe oil if only small supplies were obtained. However, such finds might lead to greater local settlement and the foundation of industries at inland centres, and from these points of view it is worthy of consideration.

Mr. Carne's objections also apply to the second section, that covered by post-tertiary and tertiary sediments in the south-western section of the State. So far as they have been examined these beds are practically horizontal and attain no very great thickness. In the neighbourhood of the Murray River fossiliferous tertiary deposits of marine types are known in New South Wales as in South Australia and Victoria, but up to the present nothing has been found in them that would suggest that they were structurally or otherwise favorable.

* Geol. Mem. No. 3, Kerosene Shale Deposits, Geol. Surv., N.S.W., 1893, pp. 105, 106.

† A. Wade, "The Possibility of Oil Discovery in Queensland," Commonwealth of Australia, No. F 4101, 1925, p. 23, *et seq.*

Finally, we come to the coastal belt. Where this is occupied by granites and the metamorphosed Older Palæozoic rocks it needs no attention whatever by the seeker after supplies of petroleum. We turn then to the two basins in this area which are filled with little altered sediments of newer Palæozoic and Mesozoic ages. Mr. Leo J. Jones, of the New South Wales Geological Survey, in a very interesting and informative bulletin,* has dealt very fully with the efforts which have been made to discover oil in New South Wales. He eliminates the Clarence River area from the possible areas in the State on account of the paucity of organic remains, the conditions of sedimentation, and the fact that innumerable artesian bores sunk in this area have disclosed not a single trace of oil. I have personally seen something of this series near the Queensland border, and am not at all impressed with the possibilities of obtaining oil from these beds.

We are now left with the Sydney Basin, with its enormous thicknesses of little altered rocks of Newer Palæozoic and Mesozoic ages, its great coal-fields, and its rich deposits of kerosene shales; an area, too, of great commercial and industrial activity, thickly populated in parts, and from every point of view demanding more close attention than any of the other regions dealt with.

Briefly, the geological sequence in descending order in the Sydney Basin is as follows:—

Mesozoic—

Triassic—

Wianamatta Stage—

Shales with occasional bands of sandstone and thin argillaceous limestone.

Hawkesbury Stage—

Massive sandstones with occasional beds of shale, grits, and conglomerates.

Narrabeen Stage—

Chiefly tuffaceous shales with sandstones and conglomerates.

Palæozoic

Permo-Carboniferous—

Upper or Newcastle Coal Measures—

Dempsey Measures—

Barren fresh-water beds.

Middle, Tomago, or East Maitland Coal Measures—

Upper Marine Series—

Conglomerates, sandstones, shales, occasional glacial erratics, contemporaneous lavas and tuffs.

Lower or Greta Coal Measures—

Lower Marine Series—

Sandstones, mudstones, conglomerates, limestones, contemporaneous lavas, tuffs, and glacial boulder beds.

Carboniferous

Claystones, sandstones, conglomerates, limestones, a glacial stage, and contemporaneous lava flows.

We can again eliminate from this sequence the beds of Triassic age. Great ravines in the Blue Mountains and down to the coast cut through these rocks from top to bottom, so that even if oil had been present in bygone times all traces of it have now disappeared. In any case the beds are not suitable in type, mode of origin, or structure to be or to have been possible sources of petroleum. With regard to the carboniferous series at the base, which attain a thickness of 20,000 feet to the north-west of Newcastle. Mr. Leo Jones states that † "The absence of oil may possibly be accounted for by the fact that the beds have undergone considerable disturbance, have been fractured and faulted as a result of earth movements and metamorphosed by extensive granite intrusions, factors that would tend to dissipate any oil or gas that the beds might contain." Structures that are probably good exist in these beds, but from an inspection of sections and from other obtainable data I could not recommend any drilling for oil in them.

Thus we have run down the problem to an investigation of the remaining Permo-Carboniferous or (according to Prof. Sir. T. W. Edgeworth David) Permian, deposits of the Sydney Basin which cover an area of 16,550 square miles, and since there are many things to be said in favour of this series, and since, therefore, I paid more attention to areas occupied by these rocks in the field, it is my intention to deal with this part of the investigation separately and in more detail.

* Notes on Petroleum and Natural Gas and the Possibility of their Occurrence in New South Wales. Geol. Surv., Mineral Resources Bulletin, No. 31, 1921, pp. 33-38.

† Loc. cit. p. 45.

In the course of this work I benefited from discussions with Prof. Sir Edgeworth David, Mr. E. C. Andrews, the Chief Government Geologist of New South Wales, and members of his staff, who assisted also in supplying maps and literature. With regard to the field work, I am especially indebted to Mr. H. C. Millard, Geologist for the Hunter River Oil Company, who has been engaged in field work in the Hunter River area for, I believe, over two years. Mr. Millard accompanied me for the greater part of the time that I spent in field work in this area, and as a patient and careful observer he had collected much information which he placed fully at my disposal. The consequent saving of time and trouble can only be appreciated by a field geologist.

II. THE PERMO-CARBONIFEROUS STRATA OF THE SYDNEY BASIN.

I. GENERAL DESCRIPTION OF STRATA.

The strata of the Permo-Carboniferous system of New South Wales have been classified in descending order as follows :—

1. Upper or Newcastle Coal Measures. Fresh-water deposits : shales, sandstones, conglomerates : 120 feet of coal in seams varying from 3 feet to 27 feet in thickness. Maximum thickness, 1,600 feet.
2. Dempsey Stage Fresh-water strata, devoid of workable coal seams ; mostly shales with some sandstone. Thickness varies from 200 to 2,000 feet.
3. Middle or Tomago Coal Measures Fresh-water deposits : similar to the Upper Coal Measures, with 30 feet of coal in seams from 3 feet to 10 feet thick. Thickness varies from 500 to 1,800 feet.
4. Upper Marine Series—
 Crinoidal Shales Cherts and cherty shales of tuffaceous origin overlying clay shales. Thickness, 2,500 feet to 3,000 feet.
 Muree Rock Sandstones with a strong persistent conglomerate at base. Thickness, 400 feet.
 Branxton Beds Mudstones containing fairly large erratics, with conglomerate or sandstone at base. Thickness, 2,400 feet to 3,000 feet. Maximum total thickness of series, 6,400 feet.
5. Lower or Greta Coal Measures Fresh-water deposits : sandstones, clay shales, conglomerates, and ironstones, with coal seams totalling from 15 feet to 43 feet in thickness. Thickness from 100 to 300 feet.
6. Lower Marine Series—
 Farley Stage Chiefly sandstones ; massive and persistent Ravensfield sandstone at base. Thickness, 1,000 feet.
 Lochinvar Stage Chiefly mudstones and shales containing much volcanic ash, tuffaceous sandstones, and occasional sheets of lava : well-marked glacial horizon at base. Maximum total thickness, 4,800 feet.

Total thickness of Permo-Carboniferous strata about 17,000 feet.

Fossil remains of marine organisms of very diverse types are very abundant on certain horizons both in the Upper and Lower Marine Series.

2. GENERAL CONSIDERATION OF THE STRATA WITH REGARD TO OIL.

Now, the upper part of this sequence, the Upper and Middle Coal Measures, and the intervening Dempsey Beds have been extensively prospected by the drilling of test bores for coal, and opened up by the sinking of shafts and the development of workings along the seams during the greater part of the past century without the recorded discovery of any trace of oil. Gas has been met with, but not in greater quantities than is usual in such circumstances, and of the type which one expects to find associated with coal measures and not in connexion with accumulations of oil. The same can be said of the Lower or Greta Measures. Numerous collieries are working in the Greta seams around Maitland, Cessnock, Greta, and Branxton, and no oil is reported either from bores, shafts, or workings.

In both northern and southern areas each of the coal-bearing stages has been seriously affected in places by volcanic intrusions. In dealing with "The Coal Resources of New South Wales,"* the Government Geologists state that "The Greta Coal Measures in the northern part of the State have been intruded by granites and quartz-felsites, which have destroyed a considerable proportion of the coal, and in all parts of the main coal basin the Upper Coal Measures have been intersected by intrusive dykes, though their effect upon the coal is more noticeable in some cases than in others," and cases are given where Upper and Middle Coal Measure seams were converted into natural coke or completely cindered. It is also stated that "It is in the Southern coal-field however, that the greatest effect of intrusion upon the coal seams is noticeable," and "that large areas have been converted into natural coke."

If oil is to be found then even in the Permo-Carboniferous Strata it must be limited to the Upper or Lower Marine Series, and especially where these deposits attain their maximum development in the Hunter River area which, so far as can be ascertained, is the only area in which the full sequence of the Permo-Carboniferous System is present. Considerable thinning of certain horizons appears to take place to the south and west of the Hunter River area. The Lower Marine Series make no appearance on the southern and western margins, while the Upper Marine, so far as is known, consist solely of conglomerates on the western rim, where it rests directly upon a contorted series of Devonian age, while a series of volcanic lavas and tuffs, over 1,700 feet in thickness, form the upper portion of the Upper Marine Series, and come immediately below the Upper Coal Measures in the southern area. Below these volcanic beds come 3,000 feet of deposits containing marine fossils and consisting of tuffaceous shales, grits, sandstones, and conglomerates, which also belong to the Upper Marine period.

3. STRUCTURAL FEATURES CONSIDERED WITH REGARD TO OIL.

As previously stated, the Permo-Carboniferous rocks form a basin which covers a very extensive area around Sydney. As a rule the beds dip at very low angles towards the centre of the depression, and there is an absence of the kind of folding that is necessary for the accumulation of petroleum, excepting in one or two areas towards the margins, where on the other hand the beds have been seriously fractured and faulted, the displacement of broken blocks being sometimes very considerable. The top of the coal measures lies at a depth of nearly 3,000 feet below Sydney, which is near the lowest part of the basin, an upper seam being worked at Balmain, on the Harbour frontage. What may be present below this depth can only be surmised. The centre of a syndinal depression of this nature is quite unfavorable for the accumulation of oil, so attention must be confined to the marginal areas where the beds are uplifted, and especially to those areas where uplift has been accompanied by folding. One such folded area occurs to the west of Penrith and Richmond, towards the western rim of the Basin. Here a sharp monoclinal fold affects both the Triassic and Permo-Carboniferous rocks. A monoclinal fold of this character is not unfavorable to the accumulation of oil, especially if it be terraced, and some closure of the terraced structures can be indicated by detailed geological work, and, moreover, if other necessary factors are present. I am unable to discover that any such work has been carried out or that any closed geological structure has been found. However, some drilling for oil has been done in this vicinity, one bore reaching a depth of 2,700 feet, but the results were entirely disappointing. The reasons for failure are well set out in the bulletin by Mr. Leo J. Jones already cited.†

In any case to bore through the Triassic and Permo-Carboniferous Coal Measures in order to test the underlying Marine Series, i.e., to a depth possibly of over 4,000 feet, would be a great waste of energy when the same beds can be tested elsewhere and under more favorable conditions without the necessity for drilling through any overlying cover whatsoever.

Due west of the Penrith area and on the uplift side of this monoclinal fold, at an elevation of 3,263 feet above sea level, a bore was put down by Mr. John Fell's Company at Hartley Vale to test for the presence of kerosene shale. This bore is said to have ended in the Upper Marine Series at a depth of 1,366 feet, but found no traces of petroleum.

The most suitable geological structures for the accumulation and retention of petroleum that I have been able to discover in this region occur on the northern rim in the Hunter River area. Professor Sir T. W. Edgeworth David has shown that this northern margin has been subjected to stresses which have produced both folding and faulting on a considerable scale, and his detailed map shows at least one closed or partly-closed structure, the Lochinvar Dome.‡ Mr. H. C. Millard, Geologist for the Hunter River Oil Company, has, during the past two years, made a careful study of this area, adopting up-to-date oil-field methods. By running structural contour lines on a definite geological horizon, he has clearly defined the structure and the nature of the closure. The Lochinvar Dome is very badly fractured in places, faults displacing the strata

* Bulletin No. 6, by the Staff of the Geological Survey, pp. 23-24. Department of Mines, Geol. Surv., Sydney, 1924.

† Loc. cit. pp. 25-33.

‡ The Geology of the Hunter River Coal Measures, N.S.W., Memoirs of the Geological Survey of N.S.W., No. 1, Sydney, 1907.



[Photo., A. Wade,

Part of the hitherto unmarked Outcrop of the Muree Rock, Upper Marine Series, west of Branxton.



[Photo., A. Wade,

Tuffaceous Sandstone and Volcanic Agglomerates, Lower Marine Series, Railway Cutting near Allandale.

present in it by several thousands of feet. To the west, however, Mr. Millard found another dome of smaller area near the village of Belford which is practically unbroken.* Professor David had already indicated anticlinal conditions in this vicinity, but it was left for Millard to prove the closure of the structure and its dome-like character. It is necessary to give both these structures, the Lochinvar and the Belford Domes, very careful consideration, for undoubtedly they exhibit the most suitable structural features that I have seen so far during my investigations in Australia.

4. THE LOCHINVAR AND BELFORD DOMES.

The geological map accompanying this section of my Report gives an adequate idea of the nature of these two dome-like structures and the configuration of the outcroppings of the beds which have been so folded. The map is based on Professor David's map of the area, with two or three modifications. The oval line of outcrop of the Muree Beds around the Dome at Belford is based on Mr. Millard's field work, and was checked in the field by myself. The swing round to the north-west of the Muree Beds in the outcrop west of Branxton, indicating a synclinal structure in this locality, is based on my own field observations, as is also the faulting in the Muree Beds shown on Wallis Creek to the east of Cessnock. Both these modifications were checked in the field by Mr. Millard. A full geological description of the area in great detail is contained in Professor David's work already cited,† and a further very useful account of the geology of the area, with a note by Professor C. A. Sussmilleh, is given by Professor David in the Guide Book to the Excursion to the Hunter River District issued in connexion with the Pan-Pacific Science Congress held in Sydney, 1923.‡

The map shows the Lochinvar Dome to be a distorted and broken structure, the centre of which is occupied by the Lower Marine Series, surrounded by the somewhat irregular outcrops of the Lower or Greta Coal Measures and the Upper Marine Series, while the Middle and Upper Coal Measures lie in the synclinal depressions to east and west. To the south and south-west the Triassic rocks, with bold escarpments, formed by the Hawkesbury sandstones, come close to the margin of the folding, and lie with marked unconformity on the Upper Marine Series at the head of Coongewai Creek. To the north the structure is open, and rocks of Carboniferous age outcrop from beneath the Lower Marine Series.

About the centre of the Dome, south of Lochinvar, is a large mass of hypersthene andesite forming the hill of Blair Duguid. Professor David considers this to be the stump of an old volcano which was contemporaneous with the Lower Marine Series, and that the andesitic agglomerates in the Lower Marine Series, which form a conspicuous feature about 2 miles to the north, are eruptive products formed by this old volcano. In the south-east corner is another rather complex mass of volcanic lavas and tuffs forming the hill of Mt. Bright, which Professor David considers to be chiefly of Carboniferous age with the Lower Marine Series resting unconformably against its margins. This volcanic mass is much faulted, and is considered to be a "Horst," a resistant mass left standing by the fracturing and movements which have gone on in the surrounding deposits.§ I am inclined to think that these two volcanic masses have played an important part in the formation of the structure of the Lochinvar Dome.

Faulting is much more prevalent in the area than is shown in the somewhat diagrammatic map which accompanies this Report. The faults are chiefly grouped in north and south and south-east to north-west directions. The north and south lines are practically parallel to the main axis followed by the fold in its northern part, and which it would apparently continue to follow in the southern portion but for later influences which have considerably distorted it in this direction. These fractures are older than those which occur on south-east and north-west lines, and are shown by Professor David to be displaced by the latter when these newer faults cut across them, and this would be expected from the nature of the structure. The north and south fault which runs along the western margin of the Dome is known as the Elderslee Fault. It has a down-throw to the west which increases from 1,100 feet to perhaps 5,000 feet as we proceed from south to north. The large fault which cut across the Dome from south-west to north-west south of Greta and Branxton is called the Greta Fault, and has a maximum down-throw to the north-east of 1,100 feet.

The re-entrant angle bounded north, south, and east by the outcrops of the Greta Coal Measures around Branxton is a down-faulted block which is synclinal in character. This is shown by the well-marked syncline in the Muree Beds which outcrop in this area to the west of Branxton. It is curious how this feature is paralleled by the outcropping beds right across the Dome on this line, i.e., approximately on the line followed by the Greta Fault. The Ravensfield sandstone follows this curve on both sides of the Dome, so does the outcrop of the Lower or Greta

* A little faulting is observable in a railway cutting east of Belford which exposes the crest of this anticline. One fault is a small overthrust from the east.

† Mem. of the Geol. Surv. of N.S.W.—Geol. No. 4, 1907.

‡ August, 1923, pp. 10-38. See also H. C. Millard on "The Lochinvar Dome," *Industrial Australian and Mining Standard*, Melbourne, 31st July, 1924. This article contains a well-reasoned discussion of oil and gas prospects in this area.

§ Mem. of the Geol. Surv. of N.S.W.—Geology No. 4, 1907, pp. 122-124.

Coal Measures, and so, again, does the outcrop of the Muree Beds; in fact, I believe that the outcrop of the Muree Beds to the east of Cessnock forms a greater re-entrant angle than is shown on the maps. It looks as though the axis of folding had originally been north and south, and that subsequent movements from southerly directions had buckled and perhaps sheered the Dome in this central portion. I am inclined to believe that the northern section of the Dome is approximately in its original position as formed, and that instead of being thrown down by the Greta Fault, it has rather resisted the elevation, which has gone on to the south of the Greta Fault around the old volcanic mass of Blair Duguid and that the direction of force causing this elevation has not been quite vertical, but slightly inclined from the vertical to the north-west. This, of course, would entail a certain amount of sheering, and, in my opinion, would explain the peculiar structural features present, which are difficult to account for in other ways, especially in the field. Some geologist has said that much light may be thrown upon large earth structures by the close study of small things. For example, the pebbles in the conglomerates to be found in the beds which outcrop about the zone where the sheering forces would be greatest are frequently not only crushed, but distinctly sheered; in fact, more examples of sheering than of crushing were noted, and some very fine specimens were collected by us. This is not conclusive evidence, but it does throw light upon the nature of the stresses to which the beds have been subjected.

The centre of uplift is the Blair Duguid volcanic mass. Mr. Millard ran his structural contours on the persistent sandstone horizon in the Lower Marine Series called the Ravensfield Sandstone, and found that they ran in concentric lines around that mass. The contours do not close, but are truncated to the north by the Greta Fault. For complete closure, therefore, he must assume that the Greta Fault has formed a barrier which is impervious to oil and gas, and that this rather considerable fracture has not allowed any petroleum to escape which may have been present in past ages. This does sometimes happen, but not always, so the closure cannot be considered to be absolutely safe. Mr. Millard also estimates the amplitude of closure to be 900 feet, which shows very sharp folding, and that the zone of closure embraces from 6,000 to 10,000 acres of possible oil country.*

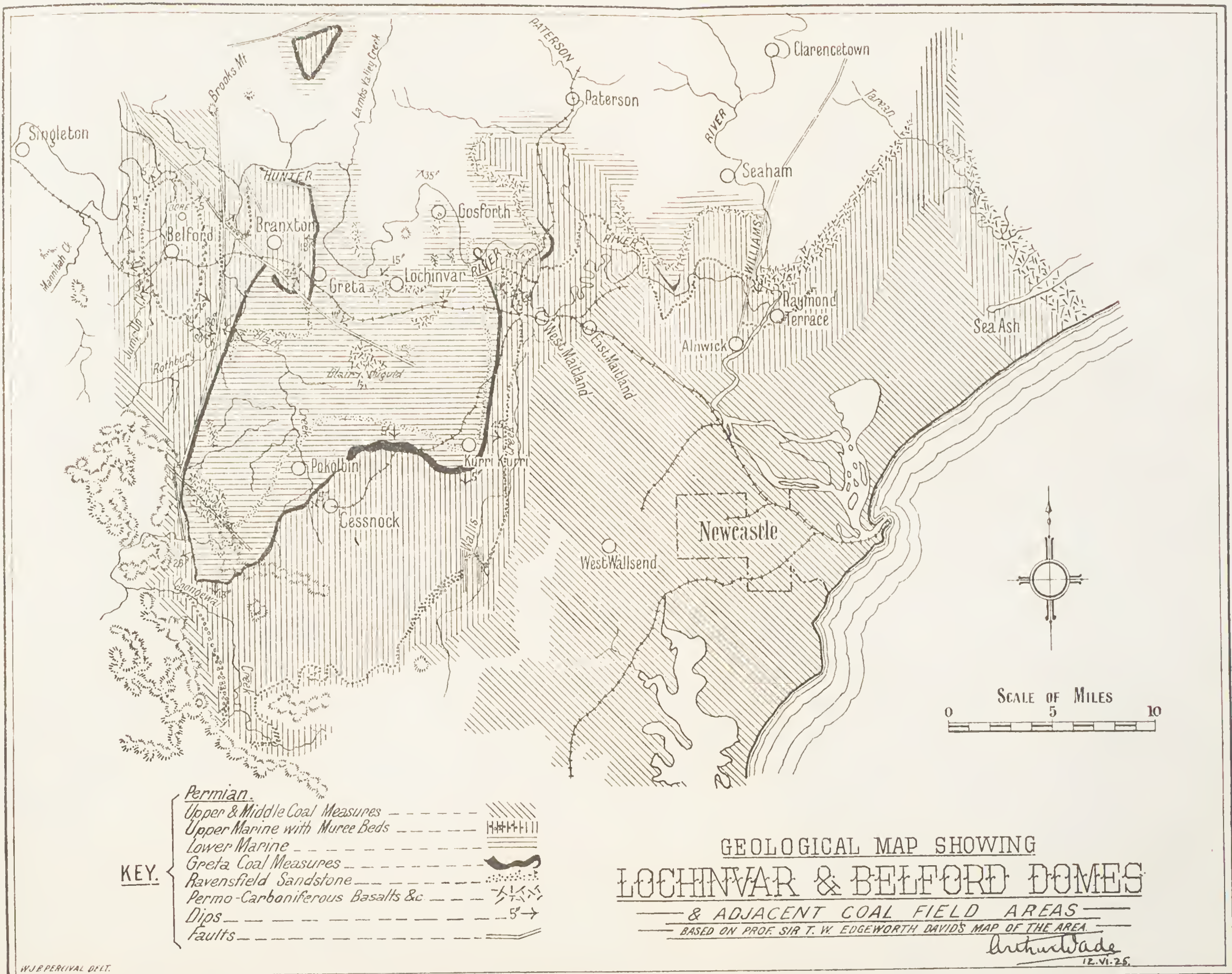
The Belford Dome is open to no objection, so far as I was able to discover, from a structural point of view. It is developed in the Branxton Beds and the Muree Rock of the Upper Marine Series. The Muree Beds outcrop in a complete oval orientated north and south; the long or north and south axis being 10 miles in length and the east and west axis 5 miles. The village of Belford lies almost exactly at the centre of the Dome. The conglomerates of the Muree Beds can be traced almost completely around the Dome, and dip off from the centre at low angles varying from 4 degrees on the east flank to 9 degrees on the west. It was formerly thought that the Lower or Greta Coal Measures lay at too great a depth below the surface in this area to be profitably worked, and Professor David's sections show the Muree Beds to be below the surface. The fact that these beds outcrop at the surface also connotes that the Greta Coal Measures come much nearer to the surface than was supposed, so near, in fact, that they can be reached in this area at a depth which would not make working unprofitable. This alone justifies the work which Mr. Millard has done, and may prove very profitable to the State of New South Wales in due course. The fact that the Greta coals come much closer to the surface in this locality has been confirmed by a boring put down at the point indicated on the map. This penetrated to a depth of about 1,460 feet and passed through 5 feet of coal at this depth. Some bursts of gas were met with during drilling operations, but I was unable to obtain particulars as to the nature of the gas.

5. EVIDENCES OF PETROLEUM IN THE SYDNEY BASIN.

No positive evidence of any importance of the existence of petroleum in the beds forming the Sydney Basin has yet been discovered. Small showings of oil on the surface of the water and in the muds of Nepean River have been referred to, but Mr. Carne and the officers of the Geological Survey point out that the spot where such showings have been noted is not far from "a long-used boat landing,"† and that motor launches and oil tins are constantly in use near this spot. Judging by the outcry which has arisen concerning the contamination of foreshores, harbours, and fishing grounds, owing to the use of crude oil by different kinds of boats, there is much force in this objection. Oil may persist for a long time on the surface of water, though it is readily carried down to the bottom by settling particles of mud, so that occurrences in such circumstances must be regarded with great suspicion. I have also heard of similar showings on the Hawkesbury River. In addition to the above objections there is an additional one in this case. While inspecting the Kerosene Shale Works at Newnes, Mr. John Fell drew my attention to a large drainage tank near the banks of the Wolgan River. Into this tank waste oil from the whole of the plant and workings is drained and saved when the plant is running. At the time of

* Loc. cit. p. 161.

† Loc. J. Jones, - Loc. cit. p. 30.



KEY.

- Permian.
Upper & Middle Coal Measures
Upper Marine with Muree Beds
Lower Marine
Greta Coal Measures
Ravensfield Sandstone
Permo-Carboniferous Basalts &c.
Dips
Faults

GEOLOGICAL MAP SHOWING LOCHINVAR & BELFORD DOMES

& ADJACENT COAL FIELD AREAS

BASED ON PROF. SIR T. W. EDGEWORTH DAVID'S MAP OF THE AREA.

Arthur Wade
12.VI.26.



my visit it still held a considerable quantity of crude oil, even though the works had been idle for a long time. Mr. Fell tells me that when the Wolgan River is very high this tank fills with water and overflows, so that large quantities of crude oil run down stream. After such an occasion the occurrences of crude oil should be very plentiful down the course of the Hawkesbury River.

With regard to the small, sometimes microscopic, showings referred to in connexion with some of the boring operations, I have pointed out in my Queensland report* that there is always a suspicion that such small quantities have been derived from the plant used for drilling, and showed that the quantity of oil found in the muds used for flushing the rotary bore at Orollo closely corresponded with that found in other bores, although in the first case the oil was undoubtedly derived from the drilling plant. Thus we have no positive evidence of the occurrence of seepages, which are beyond suspicion in this area. Again, in my Queensland report, I have dealt with the statement that oil-field areas are known in America, where no seepages occur.† This is so, but the conditions are totally different. In very few parts of the world have the strata been so little disturbed as they are in some oil-field areas in the United States. Even the older Palæozoic rocks have been so little metamorphosed that oil and gas are obtained from them at many places. Moreover, in most of such cases, beds of the same age as those underlying the surface in these areas where no seepages exist, have already been proved to carry oil in other localities. However, let us put the matter another way. Let us suppose that a corked earthenware jar is badly cracked in several places and is lying on its side, and that a number of men come that way looking for water which they know it formerly contained. The observant man will look at it, notice the jar has been badly cracked since the water was put in, the absence of any leakage of water from these cracks, and conclude that the jar is empty. The thoughtless person will notice nothing but the jar, and will open it and expect to find it still full. The optimist will say "Oh, well, the cracks are of no account; they cannot have let the water out," and he, too, will open the jar, or he may try to sell it unopened to one of the others. The man who is thirsty and whose need is great may notice the cracks with some misgiving, but will open the jar on the chance that some water is still left in it. I am afraid that the general public can be divided into each of these classes, and in any case, Australia generally is in the case of the last man, and certainly most of the areas in the Sydney Basin correspond very closely with the simile of the cracked jar lying on its side, only there is no cork in the jar. The possible oil-bearing strata outcrop in many places. All their edges come to the surface, and yet no oil-impregnated beds have yet been discovered in them.

6. THE CARBON RATIO THEORY AS APPLIED TO THE PERMO-CARBONIFEROUS DEPOSITS IN THE SYDNEY BASIN.

However, we will assume, as we are entitled to do, that some of the closed structures may contain oil or gas, and tackle the problem in another way. Again referring to my Queensland report,‡ I have discussed at some length therein the Carbon Ratio hypothesis. That is, the relation between the percentage of fixed carbon present in pure coals and the presence of petroleum supplies in neighbouring strata. The proportion of fixed carbon to volatile constituents, ash and water being excluded, stated on a percentage basis, is called the carbon ratio, and has been proved to be a measure of the amount of metamorphism that has taken place not only in the coals but in the adjacent strata. It has been found in American oil-fields that where the carbon ratio is from 50 to 55 the chances of finding oil are pretty certain. Where the ratio is from 55 to 60 there is a chance of 1 in 10 in favour of finding oil in the strata. Where it exceeds 60 the chances are so very small that they can be pretty well neglected as a business proposition.

Mr. Millard, with his usual thoroughness, obtained the results of numerous analyses of coals made by the Mines Department of New South Wales from samples taken from most of the collieries in the northern part of the Sydney Basin, and from these he worked out the carbon ratios. Subsequently he prepared a map showing the "isovolves" for the area. An "isovolve" or "isocarb" is a line drawn through points in an area where the carbon ratios are similar. It is very like the "isobars" shown on the weather charts in the newspapers, which are lines drawn through places where the barometric readings are similar. The map is published with his article, already quoted.§ The isovolve for a carbon ratio of 50 takes in that part of the Lochinvar Dome around Branxton. The 55 isovolve coincides pretty closely with the outcrop of the Greta Coal Measures, save in the west, where it runs off through Singleton and Muswellbrook. The 60 isovolve is shown running from a point near Seaham to the east of Maitland and round to the neighbourhood of Newnes, where it terminates against the Lower Palæozoic rocks. Then comes 65 to the south of the Newcastle coal-field area, while 70 and 75 are shown running through the deeper part of the Basin in the neighbourhood of Sydney.

* Loc. cit. pp. 21-25.

† Loc. cit. p. 22.

‡ Loc. cit. p. 7.

§ Loc. cit. p. 160.

Since Mr. Millard prepared this paper, the Geological Survey Department has published a later set of analyses.* In order to check Mr. Millard's isovolves, which is a very important matter, I have found it necessary to work out some hundreds of carbon ratios, not only from the analyses given in the bulletin referred to, but from an earlier edition, dated 1921, which gives analyses from different localities in some cases. In consequence, I find it necessary to criticize somewhat Mr. Millard's results in spite of the fact that I consider the lines upon which he has been working to be very sound indeed. I doubt whether it is possible to draw the 60 isovolves through the Newcastle Coal-field to the east of Maitland as shown. Out of over 70 analyses of coal from the Upper Coal Measures taken from this area, only eight gave carbon ratios that were not in excess of 60. They varied between 57.90 and 64.98. Moreover, in five cases out of these eight analyses of coals from the same pit gave results in excess of 60, showing that in these cases the low results were due to local causes. Even in the case of the lowest figure, which is from the Rhonda Colliery, and from a coal which the Geological Survey classes as inferior, a second analysis from the same pit gives a carbon ratio in excess of 60. Thus, only three results can be taken as lower than 60, and each of these is above 59. Moreover, collieries working the same seams on every side of them give higher results. The average carbon ratio for the Upper Coal Measures in the Newcastle-Maitland Coalfield area, worked out from over 70 coal analyses, is 61.5. The Middle or Tomago Coal Measures give an average, from 15 analyses, of 60.5, although a higher degree of metamorphism might perhaps be expected in these lower beds.

Turning for a moment to the western rim of the Sydney Basin, the carbon ratio averaged from 50 analyses of coals taken from the Upper Measures is 63.90, while in the Southern Coal-field area, extending from Sydney to the southern margin, the average carbon ratio, from 40 samples of coals taken from the Upper Coal Measures, reaches as high as 73.68 an individual sample going up to 84.52. In this area, however, the effect of volcanic intrusives has played a great part in cindering the coals and causing metamorphic changes to take place in the strata. The conclusion I come to from these figures is that the 60 isovolve cannot be drawn through the Sydney Basin, although there are small areas in the north-west corner in the neighbourhood of Singleton and Muswellbrook, where the carbon ratios in the Upper Coal Measures appear to average lower than 60. Thus the 60 isovolve may only be drawn to include small and relatively unimportant areas, but it cannot be represented as a line taking a general course through points in the Basin. There is apparently a progressive increase in metamorphism as we pass from the Hunter River to the south and south-west, but the basis from which it proceeds is metamorphism which is represented by a carbon ratio of over 60. This conclusion may seem rather remarkable at first sight, for Mr. Millard's isovolves for the Greta Coal Measures are substantially correct. It would appear then that there must be some progressive change between the 50 and 55 isovolves of the Greta Coal Measure areas and the Coal Measure areas around them. But here we meet a new problem: There are possibly as much as 7,000 feet of sediments between the Upper Coal Measures which we have been considering, and from which the foregoing results were obtained, and the Greta Beds. Can we assume that the degree of change which has taken place and has been traced in one set of beds has gone on to the same degree exactly in another set of beds which lie 7,000 feet below? That is to say, if the Greta seams covered the whole floor of the Sydney Basin, can we assume that the carbon ratios in the Greta stage would coincide with those of the beds above on the western and southern margins? That would be too much to assume in the present state of our knowledge. When we come to the Greta Coal Measures I think we enter upon a new problem, and that the carbon ratios of the Greta coals are a distinctly separate problem from those of the overlying Coal Measures. In other words, we complete one problem when we deal with the carbon ratios of the Upper Beds, and must start again when we consider the Greta coals.

It has been loosely stated that the carbon ratios for the Greta coals are higher than for the overlying coals. It is quite otherwise. From 70 analyses made of the Greta coals, the average carbon ratio works out at 55.5. This fact alone proves that little can be assumed in such an investigation. However, it causes some difficulty since the carbon ratio is taken to represent the degree of metamorphism which has taken place in the strata, and one would naturally expect to find this greater in beds so much lower in the sequence than in the higher ones. Mr. Millard explains this phenomenon by the following reasoning: We know that uplift was taking place in the Lochinvar area in pre-Permo-Carboniferous times, and the uplifted area may have reached such a level that it formed high land during the period of deposition of most of the upper coal-bearing sediments which were never in consequence deposited above the Greta coals in this area. Thus these coals have suffered less metamorphism, because the pressure of overlying sediments was not very considerable. Professor David and the officers of the Geological Survey do not agree with this view. In fact, Professor David states "The extra hardness of the Greta is partly to be accounted for by the fact that it has been under the pressure of an additional 7,000 or 8,000

* "The Coal Resources of New South Wales" Bulletin No. 6, dated 1924. In the only copy available, which is a proof copy, it is so dated, but it was not completed for issue till 1925.

feet of rock as compared with the Newcastle series.** Much of this was removed from the central part of the Lochinvar area before the deposition of the Triassic rocks, but there is also proof that metamorphism had gone so far as to change the carbonaceous deposits into true coals before this denudation had taken place and the Triassic sediments were laid down.† Moreover, the Greta coal seams that are now being worked occur well down on the flanks of the Lochinvar uplift. The denudation which took place between Permo-Carboniferous and Triassic times was most severe along the axis of maximum uplift, and the amount of cover which was removed must have diminished considerably as we proceed in any direction away from this axis.

However, we have still to account for the fact that the carbon ratios of the Greta coals are lower than those of the Upper Coal Measures, whereas they should apparently be higher. In studying this problem it occurred to me that the carbon ratio theorists had probably been dealing with coals of pretty uniform types of origin, and that there may be other types of coal which did not conform to the theory. I therefore set out to see whether there was any reason to suppose that the Greta coal had a different type of origin from the coals above. I first found that it was closely associated with bands of cannel coal and kerosene shale, and that the seams of bituminous coal contained patches where such coals passed gradually into kerosene shale. I had already drawn attention to the fact that carbon ratios should not be taken from oil shales or impure coals in my Queensland report,‡ since they tended to give carbon ratios which were much lower than those of true coals in the same areas. Professor David, who has studied this area more thoroughly than any other person, throws some light on the subject. He states:§ "As regards their mode of origin, the Greta coals do not exhibit roots of Vertebraria, as far as has been observed, in their underclays, nor indeed any kind of roots except perhaps very fine rootlets. From the fact that marine beds occur close underneath them as well as close above, and from the general absence of fossil wood from the seams, it has been suggested that they are of algal origin. This, however, is not borne out by the presence of Gangamopteris together with Noeggerathiopsis and Glossopteris leaves occurring in the clay bands of the seams. It seems more probable that while the climate was yet too cold for the development of large trees the seams were formed in the positions where we now find them, but out of lowly peaty growths somewhat analagous to those which have been recorded by Sir Douglas Mawson and others on sub-Antarctic Islands, such as Macquarie Island, Campbell Island, &c."|| He also states¶ that at the old Homeville mine near Farley, "the Greta Coal Measures embrace five seams varying in thickness from 2 feet up to 5 ft. 7 in., and containing an aggregate of 17 ft. 9 in. of coal. The middle seam, 4 feet in thickness, is a cannel coal, which under the microscope in thin sections seemed to be formed largely of the translucent yellow bodies named by Bertrand and Renault *Reinschia australis* and referred to by them as an alga. In places, lenticular patches up to 10 inches in thickness of kerosene shale have been found in the Greta coal seams and at Greta itself." Elsewhere, he says, that** "In places, on account of the gradually increasing proportion of the fossil known as *Reinschia australis* in the coal, the coal passes over into cannel coal, and at places into kerosene shale."

I had reached this stage in the preparation of this Report when Professor E. W. Skeats, of the Melbourne University, knowing that I was studying this problem of carbon ratios in relation to the Greta coals, drew my attention to a paper in the last issue of *Economic Geology* which had reached this country.†† It is written by an American investigator, Mr. William L. Russell, who has found very similar conditions in oil-field regions in Kentucky. Since, in my opinion, the conclusions arrived at in this paper clear up the whole problem very much on the same lines as those upon which I have been working, I shall take the liberty of quoting from it rather extensively.

Speaking of his area, Mr. Russell states that

The ordinary bituminous coals were formed in swamps and are composed chiefly of woody fibres and similar materials. The cannels, on the other hand, were formed in lakes and other bodies of water and are composed chiefly of the remains of spores, pollen, and the like. Of course, all gradations between these two types occur, and, furthermore, the bituminous coals contain some cameloid matter, the amount of which varies irregularly. Moreover, in some beds small seams of cannel coal are embedded with the bituminous matter.

The cannel coals run higher in volatile matter and lower in fixed carbon than the bituminous coals, as is well known. Though the percentage of fixed carbon (moisture and ash free) averages roughly 10 per cent. lower in the cannels, the actual amounts vary greatly, ranging from a few per cent. to 20 per cent. lower. It does not appear possible in this region to obtain the regional fixed carbon content of the bituminous coals by adding any definite amount to that of the cannel coals. About all that can be said is that the average fixed carbon content of the bituminous coals is much higher.

* Mem. Geol. Surv., N.S.W.—Geol. No. 4, p. 329.

† Mem. Geol. Surv., N.S.W.—Geol. No. 4, pp. 333 and 339.

‡ Loc. cit. p. 14.

§ Guide Book to the Excursion to the Hunter River. Pan-Pacific Science Congress, Australia.—Sydney, 1923, p. 30.

|| In response to a letter sent to Professor David, asking him whether he had noted any microscopic differences between the Greta coals and the coals of the overlying coal measures, the following reply was received on 26th June, 1925, after the report had been completed:—"In reply to your letter of 11th June, the Greta coals all carry *Reinschia australis*, more or less—the body that, when concentrated, forms kerosene shale. The Temago and Newcastle Coal Measures, as a rule, do not contain *Reinschia* to any appreciable extent."

¶ Guide Book, &c., already referred to, pp. 29 and 30.

** Mem. Geol. Surv., N.S.W.—Geol. No. 4, p. 325.

†† Relation between Isocarbit and Oil and Gas Productions in Kentucky. Econ. Geol., Vol. XX., No. 3, May, 1925, pp. 229-260.

The previous articles on the subject do not emphasize sufficiently that cannel coals should not be used in preparing isocarb maps. *If the analyses of the cannel coals were used, the maps would tend to show areas of low fixed carbon content in the regions where there was much cannel coal. As these areas would not indicate regions of low regional alteration they would greatly detract from the value of the map. In fact, a map prepared in this way might lead one to believe that certain regions in which the carbon ratios were really too high for oil and gas were altered merely to the ideal degree, and such a map would be worse than nothing.*

The whole of this, and especially the last paragraph, might very well have been written to deal with the case of the Greta coals. It describes and deals with the conditions exactly. At this point it would be well to find out just how the coal samples were taken by officials of the New South Wales Mines Department for the preparation of the coal analyses from which we have been working. In Bulletin No. 6,* from which most of the analyses were taken by myself, is the following statement: "The method adopted in sampling was to cut out a strip of coal carefully with a pick for the whole thickness of the seam as worked so that the samples should represent the coal actually sent to market." Canneloid portions of the coal are not excluded from the coals sent to market, so far as I have observed the coals trucked from the Greta area, and are, therefore, included in the samples taken. They form the best part of the coals, in any case, for gas-making purposes.

The whole of the evidence makes it quite certain that 55.5 as an average carbon ratio for the Greta Series does not represent the true state of metamorphism in these beds, and, therefore, cannot be relied upon as any indication of the possibility of obtaining oil in this area. A considerably higher figure, probably between 60 and 65 at least, would, in my opinion, represent the degree of metamorphism which exists in the Greta Series.

With regard to the occurrence of oil in this Kentucky region, Mr. Russell makes some interesting observations which may help in the consideration of our own areas. He observes that (page 253) "Nearly all the good oil and gas production from sandstones and most of that from limestones lies below the 60 per cent. isocarb. The gas pools are for the most part located between the 60 per cent. and the 62.5 per cent. isocarbs. Moreover, in the case of most of the oil pools in sandstones above 60 per cent. the ratio of gas to oil is much greater than in the case of the oil pools in sandstones below the 60 per cent. isocarb. In the pools above 60 per cent. the production is quite "spotted" owing to the irregular porosity of the sandstones. Production in these pools consists for the most part in small wells scattered among gas wells and dry holes. The area in the extreme eastern part of the State where the coals have a fixed carbon content greater than 62.5 per cent., is barren of oil or gas as yet." These conclusions would cut out practically the whole of the Sydney Basin as possible oil-producing territory, but it gives us some hope with regard to natural gas. It agrees entirely with the opinions I have reached myself.

Again, "It is noteworthy that in Kentucky as elsewhere, the coals are higher in fixed carbon in the anticlines than in the synclines." This is important, for if we are to take the Greta Measures along with the upper and middle coal measures in dealing with carbon ratios, we should, apart from the matter of the greater depth of the Greta, expect to find higher carbon ratios around the Lochinvar Anticline than in the synclinal basins on either side, whereas the reverse is the case. This again tends to show that the carbon ratios for the Greta coals do not represent the true facts. It also explains some of the low carbon ratios in certain areas which are local basins or synclines in the upper coal measures. Such low carbon ratios are to be found in the upper coal measures near Singleton, Rix's Creek, Muswellbrook, and Gunnedah in the north-western corner of the permo-carboniferous area. Small structures undoubtedly exist in this part of the country which might be prospected, especially for gas.

Mr. Russell, in a very important statement, shows that caution must be exercised in dealing with isocarbs. (Page 255). "While the isocarb map has an important use in predicting the best areas for testing, it should be understood that it merely gives an indication of one of the conditions necessary for the occurrence of oil and gas. If source rocks and porous reservoirs are not present, there will, of course, be no production no matter how ideal the isocarbs are. On the other hand, if the isocarbs are extremely unfavorable, there should be no oil or gas production, even though the other favoring conditions are present."

He considers regions where the isocarbs are generally over 62.5 to be unfavorable in spite of the presence of good structures, thick source rocks and sandstones associated with them and another area which lies between the 60 per cent. and 62.5 per cent. isocarbs, he considers as only favorable for testing for gas.

Finally, it will be instructive to quote from his conclusions (page 260):

1. In certain regions, such as the eastern coal fields of Kentucky, where the amounts of fixed carbon in the coals vary greatly, regional averages rather than single analyses must be used in making isocarb maps.
2. Cannel coals and semi-cannel coals should not be considered in making these maps.
3. In Kentucky there is a marked relation between the isocarbs and oil and gas production and the porosity of the sandstones.
4. From the standpoint of the isocarbs alone, the best place for future testing is the portions of the western coal-field, which are well below 60 per cent.

* The Coal Resources of New South Wales. By the Staff of the Geological Survey, Department of Mines. Geol. Surv., Sydney, 1924 (? 1925), p. 3.

7. CONCLUSIONS.

I am afraid, therefore, that we cannot consider even the most promising of the structures yet discovered in the Sydney Basin as possible sources of commercial supplies of petroleum, but there is hope that natural gas may be found. The beds underlying both the Lochinvar and the Belford Domes contain possible source rocks and porous reservoirs. In view of the fact that the Lochinvar structure is so broken, I consider that there is a strong probability that any gas which may formerly have been present has escaped. The Belford Dome is practically unbroken so far as I can discover, though it is bounded by faults in the synclines. I think that this dome should certainly be tested for natural gas. I can find no serious feature which is unfavorable to its occurrence in this structure. Moreover, there is the additional advantage that the extension of the Greta coals in this direction will be proved, which may alone justify the work. It may be necessary to drill deeply into the Lower Marine Series to effectively test the area, but a boring to about 3,000 feet should accomplish all that is necessary.

Small coal basins in the Upper Coal Measures exist to the north-west of the Belford area, in which the carbon ratios appear to be pretty consistently lower than 60. This district should be prospected for structural conditions with a view to testing the area for natural gas, while there is some slight promise that small oil pools may also have been preserved if favorable conditions should be proved to exist.

8. SUMMARY OF CONCLUSIONS.

1. On various grounds I have come to the conclusion that the permo-carboniferous system of the Sydney Basin constitutes the best field for exploration for oil in the State of New South Wales.

2. That the Upper Marine and Lower Marine Series of this system contain the most likely strata for the production of oil or natural gas.

3. That the most likely area is the Hunter River district on the northern and north-west margins of this basin.

4. That horizons which may possibly have been sources of oil and gas exist in the strata in this area, together with possible storage beds, and that at least one structure exists which is eminently suitable. Prospecting for similar structures should be carried out in the north-western corner of the basin.

5. That apart from the faulted nature of much of the country, the carbon ratios in the coal measures are for the most part too high for the occurrence of petroleum in commercial quantities in any part of the basin.

6. That the apparently suitable carbon ratios obtained from coals in the Lower or Greta Coal Measures are misleading owing to the nature of the coals due to peculiar mode of origin and to the presence of cannel and semi-cannel coals and kerosene shales in the coal seams. Normally, the carbon ratios should be represented by a much higher figure.

7. That the Belford Dome should be tested for natural gas by drilling to at least 3,000 feet, and that in addition to possible gas supplies of great commercial value, this boring should also prove a workable extension of the Greta Coal Measures, which provide the best export coals in Australia.

8. That there exists to the west and north-west of Belford areas in which the carbon ratios in the Upper Coal Measures are apparently more or less consistently below 60, and that these areas should be prospected in order to determine whether suitable structures exist that may be tested for supplies of natural gas; and that there may be some slight hope of the occurrence of small pools of oil in such structures if conditions should be proved to be favorable.

SECTION II.

NOTES ON THE KEROSENE SHALE DEPOSITS OF NEW SOUTH WALES, WITH A SPECIAL REFERENCE TO THE WOLGAN VALLEY WORKS.

Within a hundred miles of Sydney there exist very large deposits of the richest kerosene shales known in the world. At present little is being done to develop them. In the Wolgan Valley the mines are falling into decay, the hugh retorts are empty, and the value of the great distillation works is depreciating rapidly for want of use. This regrettable state of affairs is due to many causes, the chief of which are the rise in the costs of operation and production since pre-war days, and from this has followed the inability to compete with imported well oil products, even though these also have risen in price. Initial errors made by some of those who started the enterprise at its present location have also exercised adverse influences. Future operation of these works may be of such importance to Australia that some brief notes, based on a personal visit to the Wolgan Valley district, may be of service.

Carne's fine work "the Kerosene Shale Deposits of New South Wales,"* deals very ably with the geology and distribution of these deposits and the general properties of the shale from all points of view. He also collected and summarized all the then available information with regard to kerosene and oil shales that existed in the world. I am informed that the State Geological Survey has in preparation a bulletin dealing with the kerosene shale resources of New South Wales which will bring Carne's memoir up-to-date in many respects. Carne made no attempt to estimate the quantity of workable kerosene shale that existed in New South Wales, and contented himself with the statement that it was very large indeed. I should think that the supplies now in sight would survive at least 50 years of intensive exploitation and possibly a much greater period. R. H. Cambage, in his presidential address to the Royal Society of New South Wales, 1924, estimates "the probable reserves of kerosene shale in the Capertee-Wolgan-Glen Alice area" at approximately twenty million tons; the average content of crude oil per ton of shale at 100 gallons, giving a total quantity of 2,000,000,000 gallons, or 50,000,000 barrels available in this area. Also, "that the total quantity of kerosene shale expected to be won from deposits in the State may be approximately 40,000,000 tons, containing 3,500,000,000 gallons of crude oil." These facts are important and cannot be overlooked in view of the isolated position of Australia, the fact that well oil has not yet been produced in this continent, and the necessity for having some local source of fuel oil which could, in a time of national urgency, be relied upon for naval purposes.

The following figures were given to me, during my visit to the area, by Mr. John Fell, whose company has been controlling the work in the Wolgan Valley for some years. There is some slight discrepancy between these figures and those given by Mr. Cambage (*loc. cit.*), but Mr. Fell's figures are based on his own working experience.

The thickness of kerosene shale in the Wolgan Valley mines averages 20 inches. Actually it varies between 14 inches and 50 inches.

The yield of crude oil per ton of shale averages 101½ gallons in actual distilling.

Thirty-four retorts having a daily capacity of 6½ tons of shale are in working order, while 30 other retorts are built and could be put in order. Total, 64 retorts, with a daily capacity of 416 tons of shale. Maximum total daily output of oil would be 42,224 gallons of crude oil or over 1,000 barrels. This daily maximum would, in actual practice, never be reached since some retorts would always be idle for cleaning and other purposes. A local production of 250,000 barrels, or approximately 50,000 tons of crude oil per annum, would go a long way towards filling the requirements of Australia at the present time.

The design of Mr. Fell's retorts is based on that which has been developed in the Scotch oil shale-fields, but having regard to the differences between the New South Wales kerosene shales and the Scotch oil shales, Mr. Fell's retorts are a great improvement for local requirements. Most of the old troubles associated with retorting have been got rid of, and the present retorts work very efficiently. The cost of retorting is only a fraction of a penny per ton of shale, so that it is obvious that little saving can be effected by changes in connexion with retorting. Even if we assume that improvements could be made in methods of retorting, these could have but little effect upon price. The prime factor in costs is the cost of mining. This works out to-day at more than 30s. per ton of shale, whereas in pre-war days, it was 12s. 4d. This means that to-day it costs more than £3 to produce a ton of crude oil. The American producer in the mid-continent oil-fields area obtains about £3 a ton for crude oil delivered from the well to the pipe line. In some States it is less than this. But this figure does not represent bare cost of production but includes a very fair profit to the producer, whereas profit and the cost of transportation must be added to the figure in the case of New South Wales. If, however, the cost of production in New South Wales could be brought down to something like £1 per ton of shale, or £2 per ton of crude oil, I am of opinion that the industry would become self-supporting and profitable. To effect this, an investigation would have to be conducted into the possibility of using labour-saving devices wherever possible and of increasing the efficiency and stability of labour. These necessities are by no means so impossible of achievement as they may appear.

In addition to the retorts, there is at the Wolgan Valley works complete distillation plant, for the preparation of refined products from the crude oil. Quoting again from Mr. Cambage the products are:—

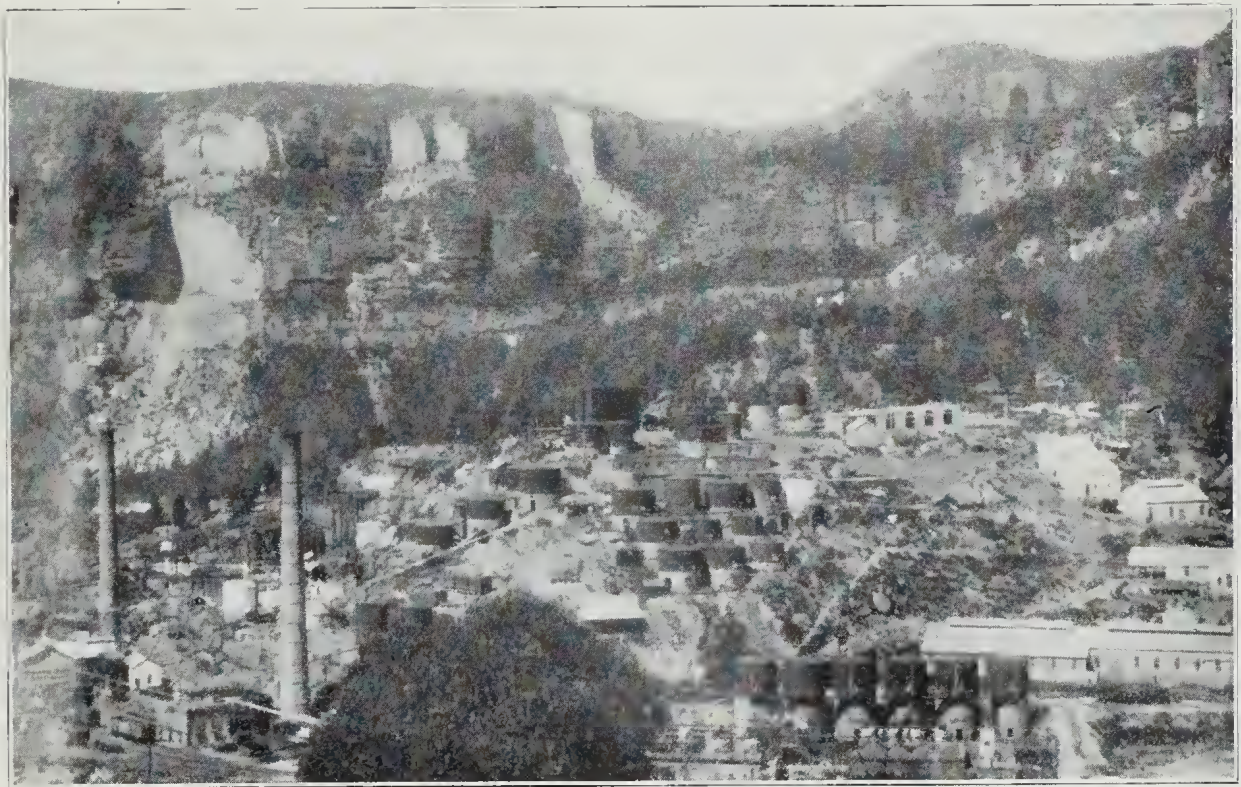
Fuel Oil	20 per cent.
Gas Oil	25 "
Kerosene	20 "
Benzine and Spirits	5 "
Paraffin Wax	5 "
Loss in treatment	25 "

By-products—1. Sulphate of ammonia (fertilizer, &c.), about 22 lbs. from 1 ton of shale.

2. Oil coke; used for household purposes.

Lubricating oils of certain grades can also be prepared from the crude product.

* J. E. Carne, F.G.S., Department of Mines, Geol. Surv. of N.S.W., Geol. No. 3, 1903.



[Photo., A. Wade.]

The Kerosene Shale Oil Retorting and Distillation Plant in the Wolgan Valley.

I believe that a representative of the firm has been studying the latest developments in refining in the United States of America, especially cracking processes, research into which during recent years has led to enormously greater yields of gasoline (petrol) from crude oils. This, besides being profitable, has helped the companies to keep step with the increasing demand for motor spirit due to the rapid development of the motor car and allied industries. The adoption of a satisfactory modern cracking process will also help to revive the industry.

The mine and works in the Wolgan Valley are situated in a deep, narrow gorge bounded by precipitous cliffs of the Hawkesbury sandstone. Access is obtained by means of a narrow gauge railway which has a fall of about 2,000 feet in a distance of less than 40 miles between its junction with the western Railway at Newnes and the floor of the valley. This means steep gradients, a high cost of upkeep and consequently expensive transportation. Moreover, the valley is not adapted to pastoral or agricultural activity, so that the line serves no purpose other than a means of communication with the shale works. The shale which is being mined at this spot is rather thin and erratic in its behaviour. The dip is more or less northerly, so that the bed is being mined down the dip slope, which is not good practice and increases costs. Possibly also, there is some adverse psychological effect on the workmen who have to live in this isolated and exceedingly confined valley, and this will have to be considered in studying the causes of the industrial troubles which have made successful development impossible in the past. Now all these adverse factors would be removed or minimized if the works could be shifted bodily over to the Capertee Valley, only a few miles to the north. The Capertee Valley is broad and fertile and is well farmed. A railway through it would be a boon to the farmer, would assist in settlement and development and would carry much produce in addition to serving the mines and works. Even the shale here is thicker. Cambage (*loc. cit.*) states that "On the Capertee side one tunnel has exposed an average thickness of between 3 and 4 feet over a distance of 4,000 feet," which is better than anything discovered on the Wolgan side. Moreover, mining can be done here with a dip in favour of the miner, thus making his work more easy and expeditious and diminishing mining costs. Workmen could be housed in surroundings which, I feel sure, would, to some extent at least, minimize labour troubles. It is possible to construct both rail and pipe line to Windsor on the Richmond branch line. The fall would be 1,065 feet spread over 78 miles, which is not excessive. The pipe line especially would be of great advantage, not only to the industry itself, but for naval and defence purposes, especially if it had an outlet in Sydney. A bold scheme on these lines would probably pay in the long run, especially with some initial State assistance. A good deal of capital is necessary, but a good deal of capital will also be necessary before the Wolgan Valley works can be put on its feet again.

With the idea of greatly reducing the cost of production, Mr. Fell carried out a daring experiment based upon a conception which suggests a spark of genius. A point was selected where the kerosene shale outcrops in the cliffs above the floor of the valley, openings were made and the shale fired *in situ*. By walling up the openings, arrangements were made to admit a current of air which could be regulated, and the gases were drawn off by means of suction through pipes of large diameter. After some initial success, falls of roof took place and interfered with the circulation system. Mr. Fell wished to open up the passages and clean out the falls, but I am told that Departmental official objected to the course on the ground of danger. Mr. Fell considers that a large body of crude oil has been formed by condensation of the gases down the dip inside the workings, which is of course quite possible. It is a pity that the experiment did not continue to prove successful, for it is quite certain that, had this been the case, oil could have been produced almost as cheaply from the shale as from oil wells. The scheme is worthy of consideration, though the difficulties in the way of continued success are obvious. Success depends to some extent upon the fact that the shale when burned does not crumble to ashy powder, but retains practically its original form and bulk. Thus there should be no falls of roof excepting in the passages for circulation of air and gas. This being the case, however, it is hard to see how air can get to the fire when the fire has penetrated into the seam to any extent, and how the circulation can be kept going without some danger to those whose duty it might be to keep the circulation ways open. I do not see, however, why some research should not be carried out to see whether these difficulties do really exist and whether they can be overcome in a satisfactory manner, if they do. The method holds out such promises if it can be worked successfully, that matters should certainly not be left without further investigation.

I should like to point out that in the long run these kerosene shales may be more profitable to Australia than oil wells, especially if only small wells and limited pools be eventually discovered. Moreover, there is no certainty that such pools will be discovered. In the meantime, the amount of shale can be ascertained definitely; we can find out what our resources are, what can be done with them, and make plans accordingly. Beds of kerosene shale are not so erratic and uncertain as oil wells. Water troubles and careless drilling will not affect them. They

remain where they are and will not " peter out " when most wanted, as oil wells sometimes do. Their profitable development will depend upon research and business methods and not so much on wild-cat speculation. I consider them to be one of the greatest assets that Australia possesses, and the day of their very great importance may yet come.

SECTION III.

NOTES ON A SUPPOSED OIL OCCURENCE AT WALCHA, NEW SOUTH WALES.

The town of Walcha is situated on the New England tableland some 200 miles due north from Sydney. The average height of the district above sea level is in excess of 3,000 feet. The town stands on highly folded and metamorphosed schists, which are regarded as belonging to the older Palæozoic period and possibly of Silurian age. To the west a large area of granitic rocks runs northward to and across the Queensland border. Patches of granite, varying largely in area, frequently break through the cover of metamorphic rocks, more frequently indeed than is indicated on the geological maps at present.

Lying more or less horizontally on the metamorphic rocks in places, are sheets of basalt, sometimes 200 to 300 feet in thickness and often showing well marked columnar structure. These are flows due to volcanic eruptions which were particularly active in many parts of Australia during the tertiary period. The sheets of lava have sometimes covered old depressions which were previously occupied by fresh water lakes or marshes, and the deposits laid down under such conditions, which have been largely removed by denudation elsewhere, have been protected and preserved by the overlying basaltic cover. These deposits consist of dark carbonaceous shales and clays, sands, blackened with humus and other carbonaceous matter and some lignite containing fragments of brittle, lignitic wood, sometimes so altered as to show the shiny, black, cleavage faces characteristic of the true coals. Prospecting for oil has been carried out by local people, and by misuse of the term " oil " for the lignitic beds and " seepage " for the outcrops, a hopeful atmosphere has been created around the venture.

The particular area examined by myself lies at the head of the Tia Valley, 26 miles to the south-east of Walcha. Cappings of basalt encircle the valley at this point, sometimes extensively decomposed into red ochreous material. The valley floor is almost level, being broken only by low rises where outlying remnants of basalt still exist ; elsewhere the low lying area is underlain entirely by the lignitic beds which cover a fairly extensive area. They have been traced for four miles to the east, and pass to the south under the basaltic cover, appearing again south of the watershed at the head-waters of Lignite Creek.

Five shallow pits have been sunk at the south-west end of the valley and have proved a thickness of about 20 feet of lignitic material. Since at the time of my visit the pits were filled with water owing to recent heavy rains, I could not ascertain the nature of the beds exposed in the pits, but it is certain that the 20 feet cannot be taken as the thickness of a bed of true lignite. The carbonaceous shales weather to a fine sticky clay containing fragments of woody matter, and this forms a cover which varies from 18 inches to 5 feet in thickness. Immediately under the basalt in places is a layer of copper blue earth due to decomposition of the basalt itself. Along the line of junction are numerous springs of fresh water. These, together with the water filling the pits, were perfectly clear and fresh and showed no signs whatever of free oil on their surfaces. It can safely be said that there is no evidence of free oil in this vicinity nor of any oil seepage, nor are they likely to occur. No doubt a little oil can be extracted from the carbonaceous matter present in these deposits by destructive distillation as it can from other brown coals, as well as oil shales and kerosene shales, but in this case, it could not be done profitably on a commercial scale. The development of the much richer and better situated kerosene shales of New South Wales has languished in a manner which is regrettable during recent years, so it is quite certain that the deposits in the Tia Valley will be of no commercial importance for many years to come.

ARTHUR WADE.

June 30th, 1925.

